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PARING AND HEAT STERILIZATION OF THE CORMS TO ELIMINATE THE BANANA ROOT WEEVIL *COSMOPOLITES SORDIDUS* GERMAR

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METHODS ADVOCATED

Various methods for rendering the corms of bananas and plantains free from the "root" or corm weevil, *Cosmopolites sordidus* Germar, before planting have been advocated.

Total immersion in water or in water with arsenicals, and fumigation with carbon bisulphide may kill the insect if prolonged, but will also kill the plant tissues.

Simmonds (1) has reported satisfactory results when the suckers were immersed in water for 21 days up to four inches above the union of the stem with the corm, allowing the rest of the stem to protrude above the surface. If immersed totally for that length of time, the suckers die. We have made one test only of this method and in that, some larvae survived by having worked their way up to the parts above water. The length of time and the special conditions required render this method cumbersome. The tendency of the larvae to work upwards may result in the destruction of the bud in some of the suckers.

The immersion in boiling water for one minute may be sufficient to kill the eggs or the very small larvae located near the surface of the corm. To reach the large larvae located deeply inside the corms, the immersion would have to be very long. A long immersion would be cumbersome and may result in the destruction of many of the corms.

The only method which has proved practical because it can be carried out quickly and inexpensively, is the paring or cutting off of the external parts of the suckers. The older corms are more irregular in shape than the suckers and are therefore more difficult to pare. Froggat (2) in 1926, recommended cutting a thin slice off the

whole sucker as far up as possible without damaging the eye or otherwise imparing its growing qualities.

We have found that cutting off a thin slice may remove the eggs but is likely to leave behind the small larvae which have started to tunnel into the corm. Such small larvae or their tunnels are difficult to detect.

In the future, heat sterilization may prove to be a practical way to free the corms of the weevil. We have done enough experimental work sterilizing infested corms at 43°C for eight hours in a circulating atmosphere saturated with moisture to show that it will free the corms from the weevil without injury. A field experiment is being conducted at the Station grounds to compare the results of paring with sterilization to determine which is more desirable.

THE NEED OF AN EFFECTIVE METHOD

Most of the banana varieties grown in Puerto Rico continue to produce satisfactory crops in most localities in spite of the weevil. Plantains, however, are so greatly injured in all localities that a second crop is usually unobtainable and even the first one is frequently a complete failure.

Plantains are greatly relished for cooking purposes and sell for about two cents each. Due to the difficulty of growing them because of the weevil, importations have to be made from Santo Domingo where the pest has not yet become prevalent. During the calendar year 1933, plantains valued at $84,690 were brought in from that island.

Bananas on fertile soil continue to produce for many years, plantains must be set into fresh soil after the second crop. Paring the suckers will serve equally well for bananas as for plantains, but the cultural practices followed render it more feasible with plantains.

PROCEDURE

The first step is to secure the best corms that can be obtained. (Fig. 1.) These should come from the least infested plantations and from stools showing few or no tunnels in the mother corms. Digging out the suckers as soon as they are large enough will also tend to reduce infestation. *All* suckers or corms are to be considered infested and conscientiously pared.

The weevils (Plate I) come out to feed and lay eggs at night. Once dug out of the soil, the suckers must be pared and removed from

PLATE I

Adult of *Cosmopolites sordidus* Germar. Twelve times natural size. (Original.)

the plantation before nightfall, because their cut surfaces are extremely attractive to the weevils, which will congregate and lay large numbers of eggs in them.

Paring will remove the eggs and the small larvae before they tunnel deeply. If the suckers are pared immediately after they are dug out, there will be less danger of the eggs hatching or of the larvae tunneling deeply.

After being pared, the suckers must be examined by the person interested in the success of the plantation. At that moment, all the outer dark tissues having been removed, any large tunnels present will become visible. Corms showing tunnels should be discarded. Ordinary laborers cannot be relied upon entirely, because they will not pare the suckers thoroughly and will pass some with tunnels as sound.

To pare, the suckers should be held by the stem. A layer one inch thick, or more, if the size of the sucker will permit, should be cut off from all over it. The outer leaf-sheaths should then be removed and the region at the union of the leaf-sheaths and the corm carefully pared (Fig. 2). Suckers reduced to three inches in diameter by paring have germinated well and produced strong plants. There should be no fear of easily injuring the corms and no need of cutting off only a thin slice. The paring should be as severe as possible.

After paring, the suckers may be planted immediately. Storing in a cool dry place for a week before planting is preferred by some growers. In that case the suckers may be stored after having been pared. To store them before paring would give the eggs the opportunity to hatch and permit the larvae to tunnel beyond reach.

The pared corms must be kept away from plantain or banana plants. Paring renders them exceedingly attractive to the weevils and they will become heavily re-infested if left within reach of the adults. Some growers have great faith in the immersion in boiling water. If it is to be practised, it should be carried out immediately after paring.

The parings should be scattered to dry out rapidly so that the eggs or small larvae in them will be killed.

OTHER PRECAUTIONS

It is useless to pare the suckers if they are to be planted in infested soil. For the soil to be free from the weevil it must have had no plantains or bananas for at least one year. It must be kept

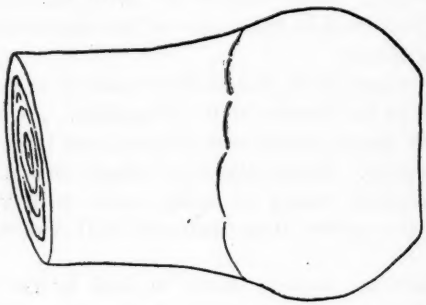

Fig. 2.—The same corm after having been pared. Note the comparative size. It is now ready to be planted. (Original.)

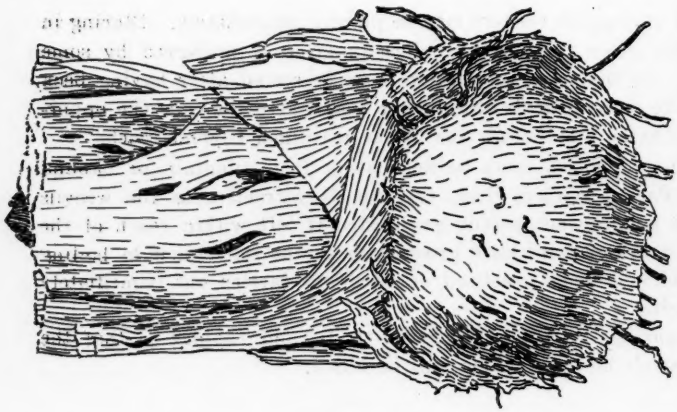

Fig. 1.—An apparently sound plantain corm. Such corms should be selected for treatment by paring, to obtain plants free from infestation by *Cosmopolites sordidus*. (Original.)

in mind that in plantations that are abandoned and allowed to die out by themselves, the corms persist for a long time and harbor the weevil.

The site for the new plantation must be removed from other plantations to prevent the beetles from crawling over or being washed down with trash by the heavy rains.

Paring may produce absolutely sound plants, but ordinarily a low percentage of infested plants is to be expected. Watch must be kept, therefore, over the plantation and any stunted plants with yellowish leaves that fail to unfurl normally should be inspected by cutting slices off the corm. If tunnels are detected, the plant must be dug out and the corm cut up to find and destroy any larvae, pupae or adults it may contain. From the more sound parts of the corm, slices are to be cut for traps. The slices are placed on the smoothed over soil where the plant was dug out. These traps attract the weevils that have migrated into the soil when they come out at night to feed. The weevils remain attached to the underside of the traps or hidden in the soil directly underneath them where they can be collected by hand and killed by dropping into cans with a little kerosene. After the surface of the traps dries out, a fresh surface can be exposed by cutting off a thin slice. After two weeks the traps should be finely chopped to destroy any larvae in them. Fresh traps should be kept on the ground until no more weevils come to them.

SUMMARY

1. Other methods of control except the paring of the corms or suckers as carried out by the writer, have been investigated and found either unreliable or unpractical. Sterilization at 43°C for eight hours in an adequate sterilizer, kills the insect without injury to the plant tissues. This method may prove to be practical.

2. Paring the suckers heavily, that is, cutting away one inch or more of all the external surface and removing also the external leaf-sheaths of its stem, will eliminate all or practically all of the eggs and the newly hatched larvae which have not yet tunneled deeply. Upon paring, the presence of larger larvae is shown by their tunnels. It is better to pare off as much as the size of the corm will allow for greater safety. Corms even when very severely pared germinate well.

3. The method can be used equally well with bananas or with plantains, but the cultural practices followed make it more desirable for plantains.

4. Suckers showing no tunnels—presumably uninfested—should

ment by paring, to obtain plants free from infestation by *Cosmopolites sordidus*. (Original.)

been pared. Note the comparative size. It is now ready to be planted. (Original.)

be selected, and even so, must be pared thoroughly. Corms showing tunnels are to be discarded.

5. Suckers for planting should be dug out as soon as they attain sufficient size. They should be taken from stools showing few or no tunnels in the mother corms and from the less infested plantations. If left on the ground overnight near plantain and banana plants, they may quickly become re-infested, especially after having been pared.

6. The paring must be supervised to make sure none of the old surface tissues are left on, or corms with tunnels passed as sound.

7. The pared corms are to be set in land free from the weevil and any plants that show infestation should be rogued and traps set to catch the weevils.

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THE DIAPAUSE PORTION OF THE LARVAL PERIOD OF *DIAPREPES ABBREVIATUS* L.

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Investigations on the life-history of *Diaprepes abbreviatus* L., initiated more than three years ago, are at present sufficiently complete to justify another report of progress. In a previous paper (1), the first part of the larval period, that of growth, has been discussed. Results of the rearings of the past year, conducted with grubs hatching from egg-clusters collected in alternate months throughout the year, indicate that little is to be added to the data there given on this part of the larval period. The variation in rapidity of growth is apparently not, to any considerate extent, due to time of year, but to the individuality of grubs, and the variation in vigor of grubs from different egg-clusters.

To eliminate possible disturbing factors in the more recent experiments, all egg-clusters were collected from a single small citrus nursery on the Station grounds at Río Piedras. At the beginning of the experiments, a single large can of soil was collected, and from this all soil used in the rearing work was taken as needed. Only rain water was used for moistening the soil. The grubs were supplied only with corn for food. All of the cans containing the growing grubs were kept in the same desk drawer, and, so far as possible, received the same treatment. The soil in the cans was maintained at a uniform humidity, so that ordinarily a single medicine-dropperfull of water at two-day intervals restored it to optimum humidity. The cans were examined three times a week; partly eaten corn and too large seedlings removed, growth of the grubs observed and recorded, fresh food and water added, and each can promptly returned to its place in the drawer beside the others. No record was kept of temperatures, but they were substantially the same as those recorded for the Station in the official Weather Bureau kiosk a few hundred feet distant.

One grub, from an egg-cluster hatching September 7, 1933, molted to eighth instar (which is considered the equivalent of having attained full growth) in 48 days, and two other individuals from this same exceptionally vigorous egg-cluster molted to eighth instar in 53 and 58 days, respectively. The best record for rapid growth

previously obtained was 59 days. Actually, this means little, for other individuals from the same cluster, receiving exactly the same treatment and having exactly the same opportunity to obtain food, required 100 and 119 days to attain the same size. The average period required by the 26 grubs reared from this cluster was 72 days; that of another cluster hatching in September 78 days. That of grubs from three clusters hatching in July was 86 days; that of grubs from three clusters hatching in November 85 days; of one cluster hatching in January 98 days, of another cluster hatching in January, the minimum was 100 days; of one cluster hatching in March, the minimum was 110 days. (Records for other months not yet available.) These records would appear to indicate that season of the year may have some effect, but temperatures certainly have little to do with rapidity of growth.

Admittedly, these records are obtained when the grubs are kept under what are supposed to be optimum conditions of food, cleanliness and moisture, and possibly they give little indication of what might be normal conditions in the field, especially in the more arid regions. The soundness of this criticism rests on the assumption that *Diaprepes* grubs ordinarily occur abundantly in arid or semi-arid regions; actually they are numerous mostly in irrigated fields where the soil is artificially maintained at a more or less even humidity by irrigation. In any case, the records establish a basis from which to estimate the effect of less favorable environments. That the conditions were optimum for growth is indicated by the fact that mortality among the growing grubs was practically nil, after each, in the 3rd or 4th instar, had been placed in a separate can. In the earlier instars, all the grubs from one egg-cluster were kept in one can, and the mortality due to crowding was high. Presumably, such mortality does not occur in the field, where the grubs disperse widely, and do not come in contact with each other after entering the soil. Even in the cans, crowding may not have been the only factor involved, for many more grubs survived to be transferred to separate cans out of what are designated as the more vigorous egg-clusters. No indication of vigor was to be noted in the egg-cluster itself, but the grubs from such clusters molted to second instar in a half or even a third of the time required by the grubs from other clusters. This appearance of superior vigor may be a delusion, and may have been induced entirely by a more favorable environment. Yet every effort was made to provide equally favorable environment for each egg-cluster: sprouted corn seedlings with some tender roots, in soil not quite so moist as that maintained

TYPICAL LIFE-HISTORIES
OF
Diaprepes abbreviatus L.
Dec. Jan. Feb. March April May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. March April May June July
1st larval instar
2nd
3rd
4th
5th
6th
7th
8th
9th
10th
11th
12th
13th larval instar
pupa
adult male
adult female
#36.95 (Rio Piedras)
#2.3 (Isabela)
#14 (Isabela)
#40.3 (Rio Piedras)
#45.3 (Rio Piedras)

FIGURE 3

for the older grubs. It seems hardly likely that such slight differences in environment as would not be obvious to the experienced technician would so profoundly modify the vigor of the grubs as to be apparent not only in the number surviving and the rapidity of growth in the earlier instars, but still obvious thruout the growing period.

The success in rearing the grubs in the earlier growth instars was not, until recently, equaled in that of the later period of waiting previous to pupation. Out of all the grubs reared in 1932–33, only one survived to pupate. No assignable cause for death was apparent, yet each successive examination disclosed one or more deaths. Some of the grubs gave the appearance of being partially roasted, and to reduce the temperatures to what might be normal in the field, all the cans were placed in a cellar under the library building. The maximum and minimum thermometer kept beside them indicated little difference in temperatures from those obtained in the standard Weather Bureau kiosk outside, and fatalities continued, so that by fall only one grub was alive. Obviously, some other type of container must be provided to enable the grubs to live thru this waiting period before pupation.

One possible method of reducing temperatures, comparable to what occurs in the field, would be to have the container open at the top, inducing evaporation of moisture from the exposed soil. If an abundance of moisture were supplied from below at short intervals, the difference in temperature might mean the difference between the death of the grub and its successful pupation. To obtain such a container, thick glass tubes, an inch in diameter by four inches long, open at both top and bottom, were used. The bottom was closed by means of a plaster of Paris plug, ¾ to 1½ inch in height, poured into the tube, and such tubes, with a porous bottom, were placed on moist sand. Two-thirds full of soil, they promised to offer a superior environment for the grubs. To better understand the later modifications that were found necessary in the equipment of these tubes, a fuller discussion of the activities of the grubs during this waiting period should be given.

Molting to eighth instar has arbitrarily been taken as marking the transition from the period of growth to that of waiting before pupation, as most grubs attain their maximum weight at this time. At best, however, it indicated only the average of all grubs, not the condition of any individual grub. One precocious grub (No. 14 Isabela), as recorded in the previous paper, pupated from the sixth instar, and did most of its waiting when only half grown, in the

fourth instar. (See life-history chart, Fig. 3). This was during the months of September thru November, so this period can hardly be either aestivation or hibernation. Possibly it might be called a "diapause," a general term for such periods of waiting until the proper stimulus is received for a continuation of growth or transformation to the next stage of development. In the case of the grubs of *Diaprepes*, Dr. W. Dwight Pierce advises that it might more specifically be called "delayed pupation, active diapause." Ordinarily, it occurs when the grub has attained full size. During the first part of the period, the grub is exceptionally active or restless. In the closed containers, the earth is so thoroughly churned up that the corn seeedlings come to the top with most of their roots broken off. Later, especially if the soil is exceptionally moist, the grub may form an oval chamber in which it rests quietly, or this may be extended for several inches, and possibly in nature might be quite extensive. The grub rests in the chamber, but is roused to immediate activity when disturbed, and there is nothing suggestive of dormancy in the fact that it has made a definite chamber in the soil.

The beginning of this active diapause is evidenced by the fact that the grub ceases to eat. It may nibble a bit at the corn seedlings, but usually such injuries as they sustain are caused by the restlessness of the grub, rather than by its feeding. Its tentative nibbling is in no way comparable to its voracity of a few weeks previous, when it was making most rapid gains, and often almost entirely devouring one or two, or even three, grains of corn within two days. Ordinarily, the grubs which have grown most rapidly molt to ninth or tenth, or even eleventh instar before ceasing to eat, while those which have been most leisurely in attaining full size often show signs of having attained full growth by the time they have molted to seventh instar. In general, the grubs of an egg-cluster reach full size at about the same time, or at least this is a sufficiently close approximation to the fact so that all can be treated alike at the same time. When all the grubs gave plain indications that they were no longer eating, they were transferred to the open tubes. This was in from 100 to 125 days after hatching.

The first grubs transferred were still in the stage of aimless restlessness, when they were never quiet for long. Some of these grubs apparently came to the surface of the soil, something that would rarely occur in nature, but was induced by their cramped quarters in the tube, and as they were not found later, were presumably devoured by the lizards which infested the insectary. Others not only burrowed thru the soil, but also into the plaster of Paris stopper,

thru it, and escaped into the moist sand beneath. These could be recovered, and replaced in their tube, or a fresh one, but often repeated their escape from its confined area. To confine them within the tube, fresh tubes were prepared with a round section of wire screening sunk into the stopper by pouring an additional small amount of plaster of Paris on top of the screen. Such looked well

Fig. 4. Equipment used in rearing larvae of *Diaprepes abbreviatus* L. (Original)

before being used, but the restless grubs churned up so much of the plaster of Paris above the screen that later practise consisted of placing earth directly on the screen. (In the accompanying drawing, the completed tube, before adding the grub or earth is at the left; in front of which is a small pile of the circular screens, with one erect on top. Next is a tube in use, with earth, grub and label; behind is a series of tubes containing grubs from one egg-cluster, placed together on moist sand. In front are the tin salve boxes used for rearing during the growth period, and to the right the bottle of rain

water with medicine-dropper used for maintaining constant humidity in the cans.) One later refinement was to place another bit of screen on top of the earth, somewhat retarding evaporation to be sure, but at least insuring the safety of the grubs from the omnipresent powling lizards.

Previously unused portions of earth were placed with the grub in the tube, and as this earth had been air-dry for six or eight months previously, trouble was avoided from mites, worms and other soil inhabitants that had often become numerous in the closed containers and may possibly have been contributing factors in causing the death of the grubs. The grubs were not supplied with food in the open containers. It was anticipated that the small bore of the tube would give the grubs so little room that they could be kept under constant observation. Actually, the grubs were remarkably successful in keeping hidden most of the time, and for thoro inspection, most of the earth had to be dug out of the tube until the grub was exposed. Naturally, this could not be done often, and in practise, the tubes were casually examined only once or twice a week to add additional water to the sand beneath them. Rain water was added until the sand was saturated, and sometimes if the tubes seemed dry just above the plug, water was also added from above. Actually, the soil at the bottom of the tubes was found to be always very moist, when removed, even tho the top might be a hard, dry crust.

The first indication of the success of the use of this open-top type of container in permitting the grubs to pass this period of waiting previous to pupation was given on March 1, 1934. On this date, a clear area at the side of a tube containing a grub which had hatched from the egg on September 11, 1933, was noted, which, on being more closely examined was found to be a window thru which a freshly formed pupa could be plainly seen. The window was higher than it was wide, indicating that the pupal chamber was vertical, rather than horizontal, as had been all the chambers previously made by grubs in earlier stages of their existence. The pupa was entirely milky, waxy white, and very active when the tube was picked up. Such activity is presumably normal, for in this case it had caused the window by scraping away the mud separating the chamber from the glass, and apparently serves to further enlarge the chamber after pupation and to compact its sides. The pupa rested on its anus, vigorously wiggling from side to side, and gradually revolving on this as an axis. Within a few days its eyes had darkened, somewhat obscuring the individual facets which were at first very distinct,

its claws were black and the underwings also being somewhat darker than the remainder of the pupa. When observed on March 19th, it had transformed to a soft adult.

Within a few days, similar windows were observed in other tubes, and later, all tubes were opened, to find that in most cases the grubs had formed vertical pupal chambers in their base, but equidistant from the sides so that no external indication of the chamber was visible.

Of the twenty grubs which had hatched from eggs laid in July, one had died sometime early in April, after having molted to the ninth instar after 109 days, and to the tenth instar after 248 days, on March 26th. Another died in May, from undetermined cause. Six had disappeared, presumably having been eaten by lizards, hardly a normal end for soil-inhabiting grubs, and presumably practically never occurring in nature. All the others, 12 in number, pupated some time during March, and had transformed to adult after the middle of the month or early in April.

Of the 36 larvae which had hatched from eggs laid in September, 12 pupated in March or early in April, and transformed to adult shortly afterwards. (In all observed cases, the pupal period was not more than a day or two longer or shorter than 15 days, and this may be considered normal, as is 7 days for the eggs to hatch after deposition: surprisingly definite and fixed by comparison with the elasticity of the larval period.) Of these, two had reached eighth instar in 48 and 53 days respectively, and two had required 100 and 119 days to attain full size. That is: the two grubs which grew most rapidly and the two (out of the same egg-cluster) which grew most slowly, all pupated, and shortly afterwards became adult, at practically the same time. Of the others from these clusters, 8 died or disappeared during the spring, 2 pupated in May, 5 in June, 3 in July, 2 in August, while 4 are still active larvae at the end of August.

The grub with the shortest larval period was the one first noted, which, hatching on September 11th, molted to the eleventh instar after 115 days, and was first noted as pupa after 170 days, on March 1st. It had transformed to an adult by March 19th, after 188 days. To be sure, this adult was not hard enough to emerge from the ground, but it indicates a possible rapidity of development from egg to adult of only a little more than half a year. If the progeny from this individual could develop even a little more rapidly, this would seem to indicate the possibility of two generations in a year. Actually, all data point to no such possibility, for it did not come to the surface

of the soil until April 28th, and proved to be a male. Females do not begin oviposition until several days after emerging from the ground, seven days are required for hatching, and all grubs hatching from eggs laid in the spring grow slowly and have a longer diapause period than those hatching in the summer or early fall.

As an indication of what may be expected of grubs hatching later in the year, the case of the single grub which survived from the previous year's rearing may be cited. Hatching December 24, 1932, it grew more slowly than others from this exceptionally vigorous egg-cluster from Florida, Puerto Rico, molting to the eighth instar after 91 days, and after increasingly greater intervals to the thirteenth instar after 303 days, and was one of the first grubs to be placed in an open tube, in November 1933. Its development can not be detailed thereafter, for it not only avoided the side of the tube, but when the earth was later removed, it was found that the grub had burrowed into the center of the plaster of Paris stopper so that it was completely hidden from sight. Apparently, however, it had found a suitable environment, for when the stopper was broken up on March 23, 1934, a fully formed and quite hard male adult was found. Returned to the pupal chamber, it remained alive there quietly resting until April 28th. As an aerial adult it lived until July 5th. This individual had required somewhat less than 452 days from egg to adult, which presumably is the normal complement to other individuals which completed their transformation in much less than a year. Its total life was 557 days, or slightly over 1½ year. None of the fully grown grubs which hatched from eggs laid in November, 1933, show any indication of pupation in the spring or summer of 1934, altho all have attained their complete larval growth. Interpolating with the data of the three other grubs that have been reared to pupa (reported in the previous paper), it appears that the normal life-cycle of *Diaprepes abbreviatus* is completed in a year. Adults are most abundant in the late spring and early summer, and from the eggs laid by the females at this time, grubs develop during the fall which have their resting period during the winter, pupate in March of the following spring, and emerge as adults ready to complete the cycle just a year later. This is the normal cycle.

Practically all of the grubs hatching during July and August are able to complete their development by next spring, most of those hatching in September are able to do so. Possibly a few or those hatching in October are able to complete their life-cycle within half a year, but these are the exceptions, and all those hatching during later months have the extremely long life-cycle that is completed in

the second spring following. Some grubs may pupate at times other than in the spring, but the evidence to date consists of:

1 pupa in late January (shortly before Jan. 27th).
1 pupa in February.
22 pupae in March.
2 pupae in April.
2 pupae in May.
5 pupae in June.
3 pupae in July.
2 pupae in August.
1 pupa in September.

Transformation to adult, in the case of insects with subterranean immature stages, does not necessarily mean immediate emergence of the adult and its prompt functioning to start a new life-cycle. A great diversity of habits is to be expected of *Diaprepes*, and presumably some of the adults do not emerge from the ground when most of the others do, but appearing first much later, survive to lay eggs in the fall and winter. Of fourteen adults on which observations are available, one emerged from the ground only twenty days after transformation from the pupal stage; most of them remained in the ground for a month or a month and a half; one for over three months. Adults are most abundant in the late spring, and cause the maximum of damage then by feeding on the tender leaves of citrus and avocado seedlings. Even in captivity, some adults after emergence from the soil live for two and three months, and doubtless some of them live even longer in nature. These possibilities of variation in adult behavior may explain the presence of egg-clusters in every month of the year, but regardless of how one may account for their presence, the writer has experienced no difficulty in obtaining an abundance of eggs during every month of the year, at Río Piedras. They are ever so much more abundant, however, during the late spring, and this should fit in with the normal life-cycle of a year.

Apparently the most important factor in causing the variation found in the habits of *Diaprepes* is the presence of the egg-parasite, *Tetrastichus haitiensis* Gahan. This parasite is so abundant in the late spring and early summer that 95 per cent of parasitism of *Diaprepes* egg-cluters has repeatedly been observed at this time, when the host eggs are most numerous. As the season advances, the percentage of parasitism drops rapidly, and during the winter and spring is so low that only rarely are parasitized clusters found. Thus the parasite is of great value in reducing the numbers of grubs at the

time when they would normally be most abundant, but has little effect on them at other seasons of the year when they are relatively scarce. This naturally results in the survival of the progeny of exceptional adults, late to emerge from the ground or exceptionally long-lived and slow in oviposition, which escape parasitizm in the egg-stage. It would appear that the presence of the parasite is largely resonsible for disturbing the normal life-cycle of *Diaprepes*, for many of the adults appearing each spring are from egg-clusters laid out-of-season, which have thus escaped destruction by *Tetrastichus*.

This would also explain the more pronounced seasonal abundance of *Diaprepes* where all the land is planted to cane, for under these conditions, the eggs are laid between cane leaves, the tough tissues of which effectually prevent their being parasitized by *Tetrastichus*. This has two practical applications. (1) The period of hand-collection in cane regions may well be concentrated in the months of abundance. (2) To protect young citrus nurseries from grub attack, however, collections must be continued thruout the year, for the few beetles present in the fall, winter and early spring will lay as many eggs which will develop into grubs as do the great number of beetles appearing in the late spring. The flush of beetles in the spring causes the greatest damage to the leaves of the seedlings, but to protect their roots from damage by grubs, hand-collection of adults at ALL seasons of the year is indicated as being essential.

SUMMARY

By using an open-top, porous bottomed type of individual container for grubs of *Diaprepes abbreviatus* L. during their resting or "active diapause" period previous to pupation, numerous individuals have been successfully reared to adult.

In most cases observed, pupation occurs in the spring, regardless of when the grub hatched.

Few of the many egg-clusters laid in the late spring produce grubs, because of heavy parasitization by *Tetrastichus haitiensis* Gahan, but during the remainder of the year this parasite is scarce.

Diaprepes egg-clusters have been found in every month of the year; the grubs from some of these pupating in the next spring and completing their development in little more than six months, others have an exceptionally long "active diapause" terminated by pupation in the second spring, resulting in a life-cycle of several months more than one year.

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LIMA BEAN POD-BORER CATERPILLARS OF PUERTO RICO ON THEIR WILD HOSTS

By GEORGE N. WOLCOTT, *Entomologist,*
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No observations on the various lima bean pod-borer caterpillars of Puerto Rico could be made during 1933–34, as no lima beans were commercially grown on the Island during that period. Experiments conducted during previous years in the attempted control of these caterpillars had been so inconclusive (**1**) that planting lima beans for the specific purpose of continuing them seemed hardly justified. Observations on these caterpillars were thus confined to what could be noted on their native hosts.

Quite by accident, a considerable number of plants of *Crotalaria incana* were discovered growing wild in an abandoned coconut grove on the beach between Mameyes and Luquillo, on June 25, 1933. Collections of mature pods, either green or brown, have since been made during every month in the year from these plants, or others supplanting them in the same locality, or from other plants growing elsewhere (Loíza Aldea and Isabela) under substantially similar environment. In most cases, the infestation of these pods by *Etiella zinckenella* Treit. was total, or very close to it, dropping below 90 per cent only during February, March and April, the minimum recorded (see table) being a very exceptional drop to only 60 per cent infestation for a small number of pods (40) on April 15, 1934. This appears to parallel, but not very closely, the previously recorded scarcity of this caterpillar in lima beans during the winter and early spring, and such seasonal variation is also indicated by the more careful observations made on all the pods collected from an artificial planting at Río Piedras.

INFESTATION BY CATERPILLARS OF *Etiella zinckenella* IN PODS OF *Crotalaria incana* GROWING:

On Sandy Beaches	*On Heavy Clay Soil*
June 25, 1933 at Mameyes: 100%	
	July 2 at Río Piedras (175 pods): 35%
	July 19 at Río Piedras (490 pods): 37%
	Aug. 6 at Río Piedras (368 pods): 44%
August 6, 1933 at Mameyes: 100%	
	Aug. 16 at Río Piedras (360 pods): 35%
Sept. 12, 1933 at Isabela: 85–90%	
Sept. 25 at Mameyes (160 pods): 90%	
Oct. 29 at Loíza (60 pods): 84%	
Nov. 12 at Mameyes (80 pods): 91%	
Dec. 3 at Mameyes: 91%	
Dec. 17 at Mameyes: 100%	
	Dec. 29 at Río Piedras (114 pods): 1.0%
	Jan. 13 at Río Piedras (202 pods): 2.5%
	Jan. 25 at Río Piedras (220 pods): 4.0%
Jan. 28 at Mameyes: 100%	
	Feb. 9 at Río Piedras (510 pods): 0.2%
	Feb. 20 at Río Piedras (600 pods): 13.3%
	Feb. 27 at Río Piedras (690 pods): 5%
	March 8 at Río Piedras (370 pods): 1%
March 11 at Mameyes: 87%	
	March 14 at Río Piedras (327 pods): 2%
	March 20 at Río Piedras (258 pods): 2%
	March 27 at Río Piedras (220 pods): 8.6%
March 29 at Mameyes: 93%	
	April 10 at Río Piedras (530 pods): 8%
April 15 at Mameyes (40 pods): 60.0%	
	April 20 at Río Piedras (370 pods): .00%
	April 30 at Río Piedras (220 pods): .00%
April 29 at Loíza:	
(100 brown pods): 92%	
(70 green pods): 80%	
	May 14 at Río Piedras (330 pods): 26.0%
	May 15 at Río Piedras (158 pods): 50.0%
June 25 at Mameyes (110 pods): 89%	June 20 at Río Piedras (680 pods): 15.0%

After the initial discovery of *Crotalaria incana* growing wild on the beach at Mameyes, search elsewhere showed that this species, although by no means as abundant as the common, bright, showy-flowered *Crotalaria retusa*, is nevertheless often to be found, not only on sandy beaches, but almost anywhere in abandoned areas not closely pastured, especially along roadsides and railroad tracks. A few plants from various points close to Río Piedras, but all growing on heavy clay soil, had all pods free from infestation by *Etiella*. To determine whether this was merely an accident, or a normal condi-

tion, a planting of a small bed on the Station grounds at Río Piedras was established, from which all pods were collected and examined. The results of these examinations, as shown in the accompanying table, indicates a comparable seasonal variation, together with a very definite freedom from infestation, apparently due to type of soil. Every effort was made to increase the infestation during the winter, as all infested pods from Mameyes were placed on the ground at the base of these plants, without any apparent effect at that time. These plants averaged about three feet in height before beginning to produce pods, and some attained a maximum height of four feet. A supplementary planting made at the end of January began to have flowers early in April, when the plants were only a foot high, and had matured pods by early in May, the maximum height being only 18 inches.

The pods of *Crotalaria retusa,* which never in Puerto Rico have been found infested with *Etiella zinckenella,* are smooth and shining; those of *C. incana* are distinctly hairy. Whether this is the character which determines the selection of these pods for oviposition by the female moths, or some other, can only be determined in countries where the number of alternate hosts is greater than in Puerto Rico.

On *Crotalaria incana,* the eggs are laid between the hairs, usually in the keel-shaped depression on the upper side of the pods, more rarely on the sides or beneath. "The egg is glistening white when first laid, but after a few days its upper surface becomes mottled with red spots" (**2**). Most of the eggs noted in Puerto Rico were slightly pinkish or flesh-colored, others showed the mottling noted by Dr. Flanders. In shape, the egg is oval, but rarely regular, most of those observed on *Crotalaria* being considerably flattened on the side towards the pod, and often somewhat pulled out of shape by the hairs between which they are laid. The reticulations on the egg-shell are often so irregular as to suggest no definite pattern, yet in other cases, especially when observed after the emergence of the caterpillar, they can be plainly seen to consist of a series of pyramids arranged like the conventionalized pineapple design. Out of the hundreds of eggs examined, only a single instance of parasitization by *Trichogramma minutum* Riley was noted.

Immediately before hatching, the egg is more or less dark orange towards the center. The just-hatched caterpillar is yellowish, with an enormous black head. It eats hairs and the outer skin of the pod first, making somewhat of a bower of silk and excrement and uneaten ends of the hairs, before burrowing inside. As many as eight eggs have been noted on a single *Crotalaria* pod, and often

three and four are to be found, yet rarely does more than a single caterpillar occur within. Within the pod, the caterpillar feeds on the immature seeds, making an extensive network of silken fibers and entangled excrement within the pod before it attains full size. Its later growth stages—a greenish caterpillar with black or very dark head, and in the last instar with a clear pro-thoracic shield marked with black—have previously been described (1).

The wild beach sword bean, *Canavalia maritima,* grows in abundance on the beach at Mameyes, and every time a collection of *Crotalaria incana* pods was made, incidental observations were made on the beach beans to determine a possible seasonal variation in their infestation by *Fundella cistipennis* Dyar. This caterpillar is also found attacking the pods of *Cassia occidentalis,* a common shrub springing up after cultivated crops have been harvested, or growing along roadsides. In both hosts, heavy infestations were found every time search was made for them. A careful examination of flower sprays of *Canavalia maritima* picked at Mameyes December 1, 1933, indicated that buds and flowers, as well as pods in all early stages of development, were eaten by the caterpillars. The eggs were noted in considerable abundance, in practically all cases being laid on the calyx. If the calyx of the unopened bud is fresh and plump, the egg is laid in the depression where the lower lobes fold against the upper one. On the withered calyx, the egg is laid anywhere. As many as seven eggs on a single calyx were counted. The eggs are a dark intense pink, oval in outline, tightly glued to the plant surface, and somewhat flattened in contact with it. The upper surface is finely reticulate, with an irregular pattern of somewhat elongate polygons. When about to hatch, the egg becomes grey, and soon the head of the caterpillar can be seen in motion with its jaws chewing a hole in the side. As soon as the hole is large enough, the caterpillar crawls out without delay and moves away from the empty shell. Its head is relatively enormous in size, dark brown in color, the slender body being light yellowish brown, with a central darker stripe thru the middle to mark the position of the empty alimentary canal.

On *Cassia occidentalis,* the eggs of *Fundella cistipennis* are sometimes laid on the underside of the very tender leaves, but when flower sprays are present, the majority of the eggs are found at the base of the young pods, on its torus or receptacle: the scar left by the falling off of the withered flower. When laid in this depression, the egg appears quite flat and scale-like, being almost level on the

upper, exposed surface, but even more convex where it fits into the crease of the torus.

The attempt at control of the lima bean pod-borers by means of spraying with pyrethrum was based on the assumption that this might kill the eggs or small caterpillars before they entered the pod. To test this possibility, branches of *Crotalaria incana* bearing many green pods on which the eggs of *Etiella zinckenella* had been laid were sprayed with pyragol, diluted 1 to 200 with rain water. Within the next few days, every egg hatched. The experiment was repeated, using a dilution of 1 to 100, with the same results. A third spraying (of fresh pods) with a dilution of 1 to 75 caused considerable temporary curling of the leaves, and also had no effect on the eggs. Nor was any effect to be observed on the young caterpillars.

To duplicate this experiment with the eggs of *Fundella cistipennis*, bunches of freshly picked flower clusters of *Canavalia maritima* were sprayed with pyragol, diluted 1 to 200, 1 to 100 and 1 to 75. In no case did this treatment prevent the hatching of the eggs, or kill any caterpillars. In all stages of growth, however, the caterpillars are readily susceptible to drowning, for all present overnight in pods below the water level were dead by the next morning.

These experiments indicate that the only possible value which pyrethrum might possess is in discouraging oviposition on sprayed plants. An experiment to determine this point, conducted on wild plants on the beach could not be kept under daily observation, and it was not until late in the summer of 1934 that the pods of *Crotalaria incana* at Río Piedras were sufficiently infested to be used for such an experiment. They had been planted in two rows, and one of these was sprayed with pyragol, diluted 1 to 100 with water, on August 16th, and again on August 20th, the other row being intended to serve as check. Unfortunately, the two rows were only a little over four feet apart, so that the fumes of the poison apparently also affected oviposition on the check. The first count made on the pods, August 27th, showed a drop from the July–August average of 38% to 11.1% on the sprayed row and 14.5% on the check row. The second examination of pods made on September 10th showed 16.5% infestation on 314 sprayed pods, as compared with 31.0% infestation on 83 check pods. These results are not entirely conclusive, but they appear to indicate that pyrethrum may have a definite value in preventing oviposition by the females of *Etiella zinckenella*. No comparable experiments with *Fundella cistipennis* were attempted.

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THE LARVAE OF *LYCAENA THEONUS* LUCAS FEED ON BUDS AND FLOWERS OF LIMA BEAN AND *CROTALARIA INCANA* IN PUERTO RICO

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The small, greenish, slug-like caterpillars of the little blue butterfly, *Lycaena theonus* Lucas, are reported by Bruner (1) as feeding on the pods of lima beans in Cuba. These butterflies were extremely abundant at Isabela in 1931–32 in a planting of young casuarina trees close to a field of lima beans, but the larvae were not discovered at the time. In a close examination of a few lima bean plants at Río Piedras, August 2, 1933, two larvae were noted eating the flowers and buds. One transformed to a gray pupa, from which an adult emerged which was determined by Dr. Wm. Schaus, the present being the first published record of this species from Puerto Rico.

Later, when many pods of *Crotalaria incana* were being collected at Mameyes, several caterpillars were found among the immature pods, possibly feeding upon them, or more probably on the buds and flowers. At Río Piedras, butterflies were observed hovering over the *Crotalaria* plants, and at times alighting upon them. One female was observed to oviposit, Dec. 28, 1933, on the very top of a flower spray, the egg being light bluish-green in color, turban-shaped like the illustration (Fig. 7) in Holland's "The Butterfly Book," but not so deeply sculptured, and entirely smooth in the depression on top.

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THE PRESENT STATUS OF WHITE GRUB PARASITES IN PUERTO RICO

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In less than ten years after its first introduction into Puerto Rico, the giant toad, *Bufo marinus* L., has changed the economic status of white grubs on the Island from that of a major pest to one of comparative rarity. The most obvious indication of such change is that fields of sugar cane on the South Coast, especially in the districts where grubs were formerly most abundant, can now be successfully and profitably ratooned. When white grubs were abundant, such a procedure would have been impossible; now it is the rule. Formerly the roots of sugar cane were often so completely destroyed that the stalks had to be harvested months in advance of normal maturity; now they are so numerous that plowing and replanting are obviously unnecessary. To be sure, different varieties of cane are now being grown, and some other factors have been changed, but the one of importance is that white grubs are no longer present in sufficient numbers to cause appreciable injury to the cane roots. For this changed condition, the imported toad is almost entirely responsible.

Before the toad was introduced into Puerto Rico, careful studies on the natural enemies of white grubs indicated that, altho locally some of these native parasites were at times quite abundant, their effect on the white grub population as a whole was so slight as to be inappreciable. No definite records of abundance of the parasites at this earlier period are now available, so that an exact comparison with present conditions is impossible. Quite recently, the opportunity to judge of the present status of some of those parasites was furnished by the investigations of Mr. Walter F. Jepson, sent here by the sugar planters of Mauritius to collect white grub parasites for importation into that Island.

Two species of Tachinid flies, *Cryptomeigenia aurifacies* Walton and *Eutrixoides jonesii* Walton, were first discovered attacking May beetles at Añasco in 1912 by Messrs. Doige, Van Dine and Jones, (1) and were later collected in considerable abundance at Río Piedras by E. G. Smyth. During the spring and summer of 1933, Mr. Jepson collected thousands of May beetles at Añasco, Río Piedras and Cidra,

from these recovering none of the latter species, and at Cidra only found approximately 1% of parasitism by the former.

The most extended investigations on the Scoliid wasp parasites of white grubs were conducted by Mr. H. D. Box at Aguirre (**2**), at a time when the toad had already been introduced, but before it had become sufficiently abundant to have produced an appreciable effect on the white grub population. Because of the scarcity of the Tachinid flies, Mr. Jepson concentrated his efforts on the Scoliid wasps, and the following paragraphs are taken from an informal report (**3**) which he presented to the writer shortly before his return to Mauritius.

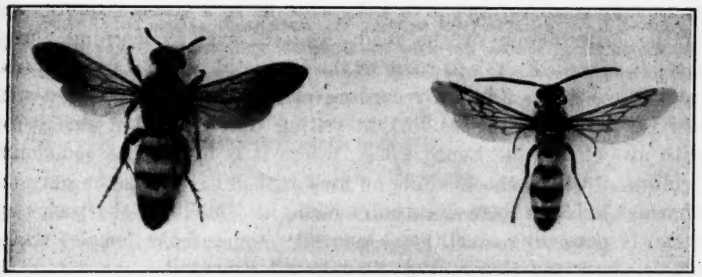

FIG. 5.—Female and male of *Campsomeris trifasciata* F. (after Box.)

"The species *Campsomeris trifasciata* F. was found by Box at only one spot near Aguirre. This locality was revisited and females found, during the present work, over eight years later. At no other locality on the South Coast has this species been found, but several females were seen at Isabela. Males have been seen, on *Mitracarpus portoricensis*, in a field at Km. 33.4 along the San Juan–Arecibo road. In addition, a locality where twenty females may be obtained in a morning has been found in the hills, on Treasure Island Plantation, Cidra, in a field of abandoned pineapples, to the right of the Camp road 150 yards beyond the packing shed. The food plant is a pink straggling labiate; the males frequenting *Mitracarpus*."

"*Elis xanthonotus* Rohwer seems, with the foregoing species, to prefer the heavier soil types, and is, in addition, absent from the South Coast belt; its attachment to *Mitracarpus* as a food plant for both sexes may in this case be a determining factor. No specimens were collected at Santa Rita (Guánica), nor on the West Coast until Isabela was reached. Many individuals have been seen on the San Juan–Arecibo road, but the place of maximum abundance discovered is at Cidra, where the females are, on sunny mornings, the commonest Hymenoptera. Up to 150 individuals have been secured in a single morning's collecting. In an adjacent field, full of *Mitracarpus*, no trace of *Elis* could be found. The flight is spasmodic and tumbling, and the range evidently not great. The greatest success in rearing this species has been on the large grubs of *Phyllophaga*

portoricensis or *vandinei*, though in the absence of these, oviposition and development takes place readily on 2nd stage grubs, and the mature grubs of *P. citri;* the cocoons being naturally much smaller on the latter species. The time of development is longer at Cidra than that recorded by Box at Aguirre, the egg stage occupies over two days against 32 hours, and the larval period 8–10 days against 5 days in the South."

"*Campsomeris pyrura* Rohwer, which was not found by Box at Aguirre, appears not uncommonly at Cidra. The males are quite abundant, both sexes frequenting *Mitracarpus*. No eggs have yet been obtained, and the species can have but little importance as a controlling agent, if, indeed, it be a parasite of *Phyllophaga* spp."

It should be noted that these later observations by Jepson, mostly at Cidra, or along the North Coast, are hardly comparable to those of Box at Aguirre, and give little clue as to a changed status due to the introduction of the toad. Indeed, even concerning *Campsomeris dorsata* F., the parasite of the Dynastid beetle, *Ligyrus tumulosus* Burmeister, Jepson, recording observations made in the summer of 1933, only echoes Box in stating that it "is but rarely met with away from the South Coast, where it is by far the commonest Scoliid". Of all the Scoliids he took with him, it was the only one of which releases were eventually made in Mauritius, the wasps apparently possessing exceptional longevity, some of the females traveling 53 days and living over 40 days after arrival.

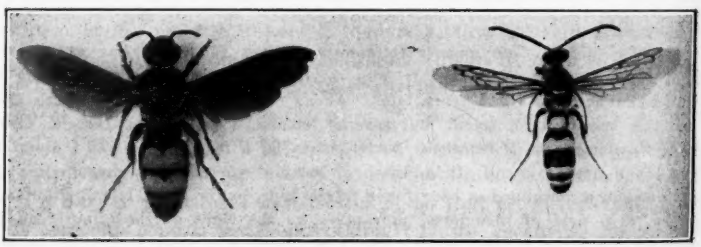

FIG. 6.—Female and male of *Campsomeris dorsata* F. (after Box.)

That *Campsomeris dorsata* was not an exclusively South Coast species was already known, for collection had been made at Maunabo, Trujillo Alto and Arecibo (**4**), but finding it in abundance on the North Coast was hardly to be anticipated. On June 7, 1933, Mr. Jepson and the writer noted several hundred males of this species resting in five or six clusters on low casuarina trees at the side of the School of Tropical Medicine, Puerta de Tierra, San Juan. So far as known, this is not only the first record of abundance on the

North Coast, but also the first record of this swarming habit of the males, similar to that which has been so often observed of *Elis haemorrhoidalis* F. The School adjoins the U. S. Army barracks, and presumably the wasps had found there an abundance of host material, as *Ligyrus* grubs feed on decaying horse and mule manure as well as on cachaza and decaying cane stools and trash in the ground.

Apparently *Campsomeris dorsata* has experienced tremendous variations in abundance in Puerto Rico, for Gundlach in 1894 (**5**) records it as rare. The earliest economic record is in a letter written by Mr. H. Bourne, at that time in charge of field experimental work for Guánica Central, from Santa Rita on June 20, 1913.

"While I was getting these grubs (of *Ligyrus tumulosus* Burm.) I found 28 cocoons of a wasp, very probably the black one with two reddish bands across the abdomen, because while digging, two flew out. This wasp is commonly seen in the *callejones* and cane fields. I also found one grub with a large size larva of a wasp attached to its body, one grub with a medium sized larva attached to it, and one with the egg of a wasp freshly laid on its body."

In May, 1934, in the fields where he made these observations, only ten or twelve females were to be noted in a morning, mostly frequenting the flowers of the common bur marigold, *Bidens pilosa* L. Nothing comparable to the thousands inferred by Bourne and recorded by Box a few years previously was to be seen, even tho all conditions were apparently propitious: an abundance of cachaza in the field (for *Ligyrus* grubs) and an abundance of flowers for the wasps. It is evident that here the toad had so changed the balance of nature that *Ligyrus* had practically disappeared, and without a host, the wasp had also almost disappeared in this its previously most abundant habitat. The observations of Mrs. Dexter (6) on the food of the toad in cane fields indicate, indeed, that the wasps themselves are eaten: that is, both host and parasite are consumed by *Bufo marinus*.

Casual observations on the apparent abundance of this wasp may be grossly inaccurate, if made at the wrong time of day. On a bright sunny morning, no female wasps are to be found before 8 o'clock, and rarely are any to be seen until 9:00 A. M. From then until 11:00 A. M., they occur in increasing abundance, the males beginning to appear about 10:30 A. M. The appearance of the males, however, indicates the beginning of the end of the presence of the females on flowers, for while the males frequent the flowers during the hottest part of the day, the females are practically never present after 11:00 A. M. except when the early morning has been cloudy. No females at all appear during cloudy weather, and none are to be seen

when a passing cloud temporarily obscures the sun. The common bur-marigold, *Bidens pilosa*, serves quite as well as a host for the females as do the flowers mentioned by Box, but the flower preferred by the females is the large yellow Calthrope, *Tribulus cistoides* L., present in considerable abundance in Puerto Rico only in San Juan and Puerta de Tierra. These flowers have a delightful perfume, suggestive of pansies, but they begin to close before noon, like the much smaller and paler yellow ones of the closely allied *Kallstroemia maxima*. Of this, Box states that "during its flowering season thousands of Hymenoptera are attracted by its delicate bloom; among the wasps, the Scoliid *Dielis dorsata* is the most frequent, and on sunny mornings thousands of the females of this species may be seen in most places where this plant occurs". A few wasps have been observed at Puerta de Tierra to feed only on this smaller yellow flower, but the great majority of them frequent only the larger and showier one. The early fading of these preferred hosts may have affected the feeding habits of the wasps to such an extent that they make no attempt to feed after these flowers are gone for the day.

During the summer of 1934, five times as many wasps were to be seen on the few patches of yellow Calthrope which encroaching building has left in existence on the wind-swept cliffs of Puerta de Tierra as at any point of the South Coast with a practically unlimited supply of flowers. Apparently the toad as a decisive factor has been practically eliminated in Puerta de Tierra by the impact of heavy urban street traffic, the few areas in which to hide during the day, and the scarcity of pools in which the immature stage might be passed. Thus, with an abundance of horse and mule manure available as host for the larva stage of *Ligyrus tumulosus*, the elimination of the chief predator (the toad) on these beetles has made possible the existence of their parasite, *Campsomeris dorsata*, in greater numbers than elsewhere in Puerto Rico.

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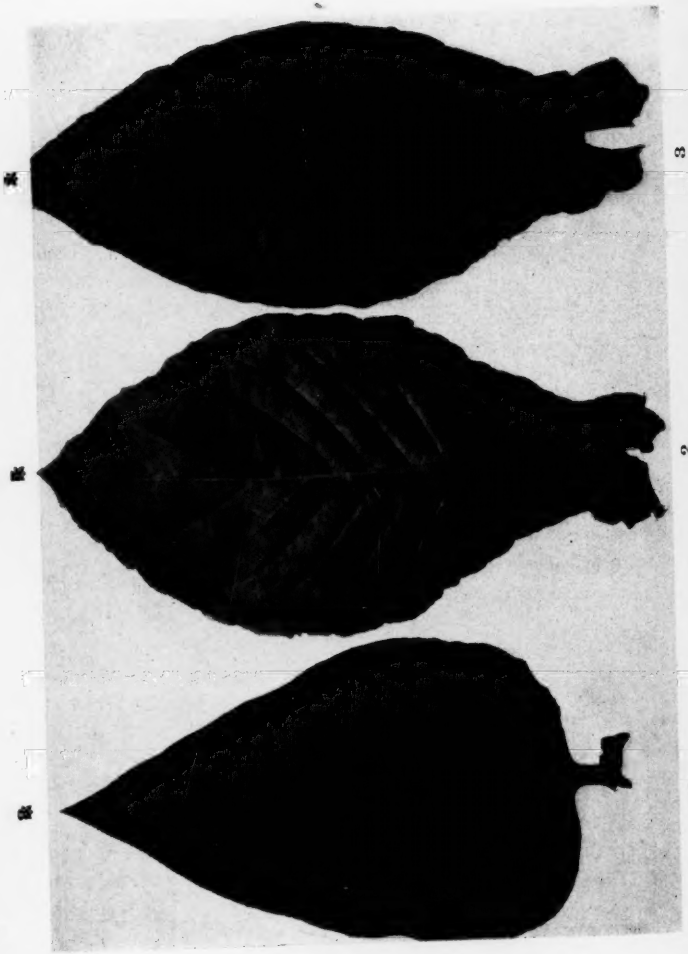
PLATE II.



EXPLANATION OF PLATE II

FIGURE 1.—Leaf of normal green Turkish tobacco.

FIGURE 2.—Leaf of No. 43, A yellowish-green "Cuban" selection to show the *yy* character of *Nicotiana glauca*.

FIGURE 3.—Leaf of "Cuban" *N. glauca* tobacco.

(The true characters have been poorly represented in the plate, the yellowish-green character is more uniformly yellow and the greens show too much of the yellow shade.)

NOTICE

By Act of the Legislature of the Insular Government of Puerto Rico, the Insular Experiment Station has been transferred from the Department of Agriculture and Commerce of Puerto Rico to the University of Puerto Rico and the name of the Station changed to Agricultural Experiment Station of the College of Agriculture and Mechanic Arts of the University of Puerto Rico.

In accordance with this change;

The present JOURNAL OF AGRICULTURE OF THE UNIVERSITY OF PUERTO RICO, starts with Volume XVIII, January 1934, and is a continuation of the JOURNAL OF THE DEPARTMENT OF AGRICULTURE OF PUERTO RICO, which suspended publication with the completion of Volume XVII, 1933.

Very truly,

MELVILLE T. COOK,
Editor.